Downscaling and Data Assimilation in the Early Instrumental Period: *Insights from First Simulations*

Lucas Pfister[1,2], Peter Stucki[1,2], Andrey Martynov[1,2], Stefan Brönnimann[1,2]

[1] Institute of Geography, University of Bern, Switzerland
[2] Oeschger Centre for Climate Change Research, University of Bern, Switzerland

Motivation

Global historical reanalyses are a valuable database for the weather reconstruction community. Using regional weather forecasting models and data assimilation systems, these datasets can be further refined to a regional-to-local scale, allowing a more detailed analysis of atmospheric processes and surface effects. But what if we go far back into the past, to the early 19th century, where only a couple of meteorological observations exist?

This poster presents first, explorative results and insights from an experiment, in which we tried to reconstruct the weather of the summer 1816 in Europe – a particularly interesting episode due to the catastrophic aftereffects of the Tambora eruption. Using the Weather Research and Forecast (WRF) model for downscaling with input data from the the newest version of the 20th century reanalysis (20CRv3), we reconstructed the coldest episode of this summer. Furthermore, we tried to refine the reconstructions by assimilating station data, that was digitized in the framework of recent data rescue activities, using a 3DVAR-approach.

However, downscaling and data assimilation in the early instrumental period present some particular challenges, which we like to illustrate here.

Data & Methods

WRF version 4.1.2
Nesting with 3 domains
27 – 9 – 3 km resolution
hourly output
04.06.1816 – 13.06.1816
spectral nudging in D01
(optional, not with DA)

Data assimilation (WRFDA)
3DVAR
3-hourly analysis timestep with 3-hour window
BE covariance matrix from 12/24h WRF forecasts
Observation errors = constant

Boundary Conditions
20CRv3
3-hourly ensemble mean

Station Data
17 Stations (2 for validation)
partly homogenised
pressure & temperature

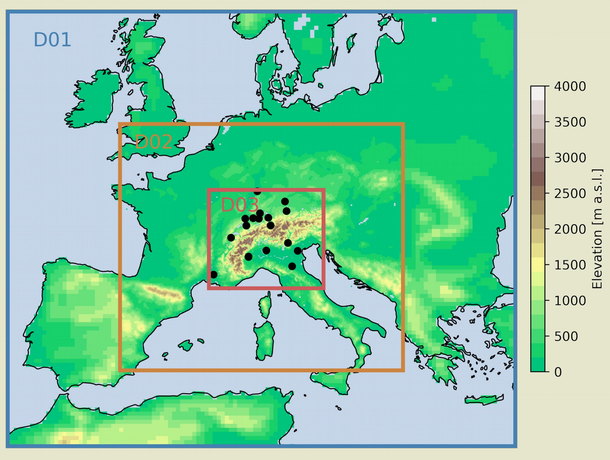

Figure 1: WRF domain setup with locations of station measurements (black dots).

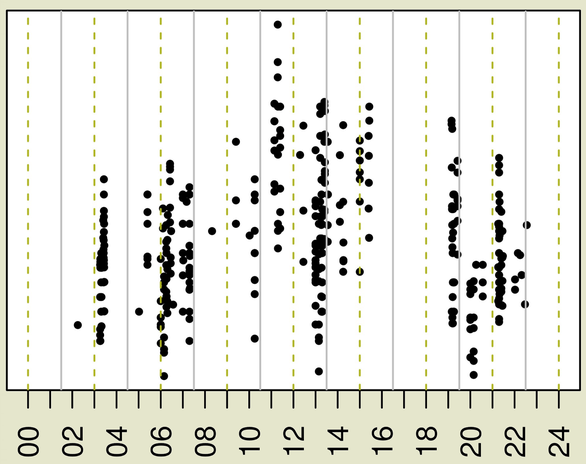

Figure 2: distribution of observation times of station series (black dots), analysis timesteps (green dotted lines) and windows (grey lines).

Challenges & Results

Land Use

Changes of land use in the last 200 years were analysed. WRF simulations were performed using USGS land use categories, as well as corresponding land use data for 1800 from the Anthromes v2 dataset.

Only minimal differences were found in the results, with exception of nighttime temperatures where urban areas expanded since 1800. These might however be important for data assimilation, as many series were measured in urban areas.

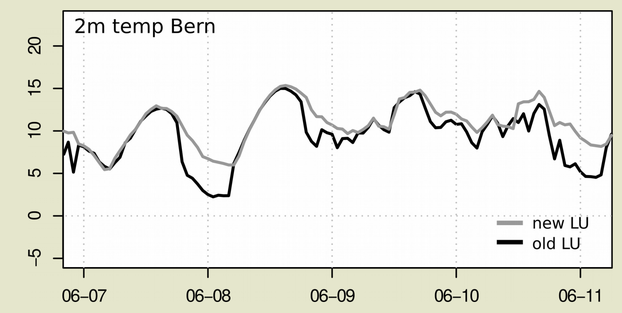

Figure 3: 2m temperature from WRF output with current (grey) and historical (black) land use data.

Quality of observations

Early instrumental measurements are sparse in time and space – and the more valuable for quantitative reconstructions of daily weather variability at a local scale, and for validation purposes. In fact, the measurements were typically taken with great care, the equipment was very well maintained. However, potential deficiencies remain w.r.t. homogeneity among the stations or observation times, among others.

Here, we assimilate temperature and pressure data only, and we allow rather large errors for the first experiments (3 °C, 2.5 hPa).

Preliminary results

Figure 4 and 5 show first results from different WRF-simulations and data assimilation (compared to independent station data).

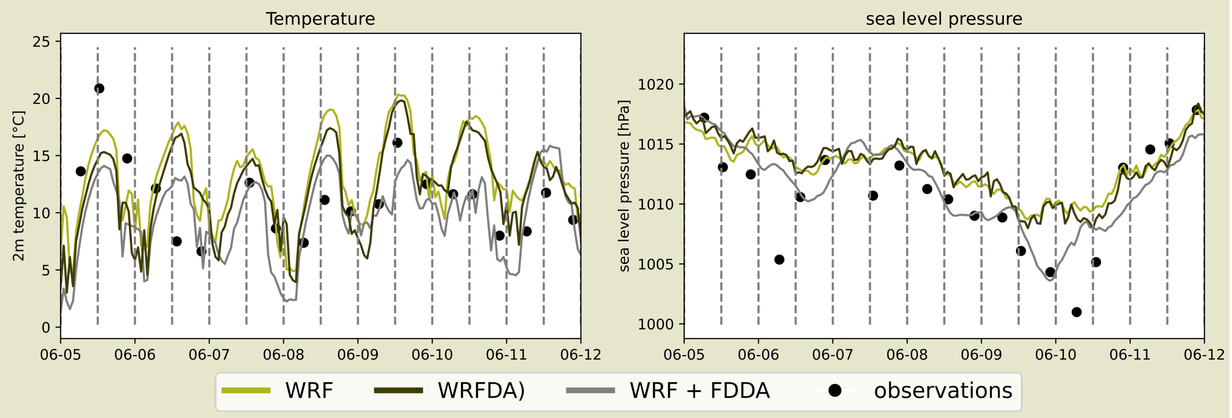

Figure 4: comparison of 2m temperature and sea level pressure at Station location of Bern between outputs of WRF, WRF with data assimilation (WRFDA) and WRF with spectral nudging (WRF + FDDA) and station observations.

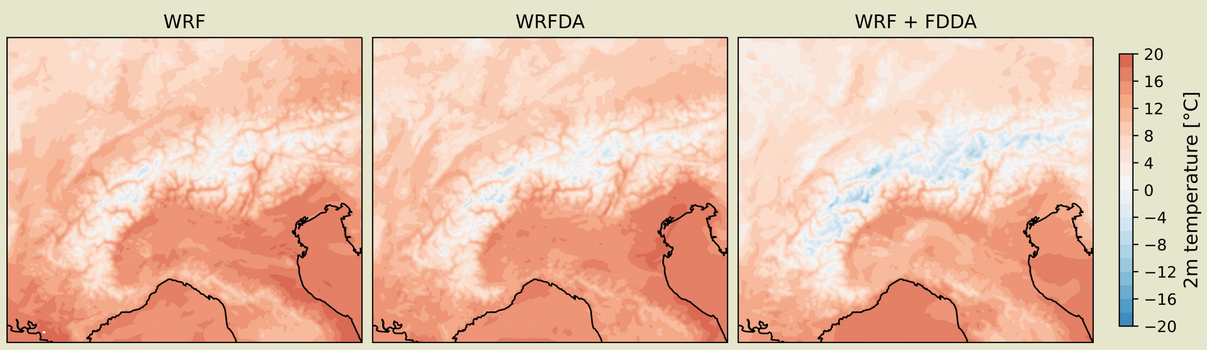

Figure 5: comparison of 2m temperature from outputs of WRF, WRF with data assimilation (WRFDA) and WRF with spectral nuding (WRF + FDDA) in domain 03 at 1816-06-07 at 06:00 UTC..

Discussion & Conclusions

Although challenging, results from WRF/DA-simulations provide realistic results given the focus on the early instrumental era. First results suggest that:

- adapting the land use scheme to contemporary categories gives very similar results except for heavily urbanized regions
- spectral nudging in the outermost domain actually brings the simulated values of temperature and pressure closer to observed station data

Further analyses may involve

- different specifications of the data assimilation system (e.g. smaller estimated errors; coupling of spectral nudging and data assimilation).
- homogeneization of the station data, which may be difficult, but should be envisaged where possible.
- longer periods of study to enhance robustness of the findings

References

Brugnara, Y., et al.: A collection of sub-daily pressure and temperature observations for the early instrumental period with a focus on the “year without a summer” 1816, Clim. Past, 11(8), 1027–1047, doi:10.5194/cp-11-1027-2015, 2015.
Brugnara, Y., Pfister, L. M., Villiger, L., Rohr, C., Alessandro Isotta, F., Brönnimann, S., Isotta, F. A. and Brönnimann, S.: Early instrumental meteorological observations in Switzerland: 1708?1873, Earth Syst. Sci. Data, 12(2), 1179–1190, doi:10.5194/essd-12-1179-2020, 2020.
Ellis, E. C., Goldewijk, K. K., Siebert, S., Lightman, D. and Ramankutty, N.: Anthropogenic transformation of the biomes, 1700 to 2000, Glob. Ecol. Biogeogr., 19(5), 589–606, doi:10.1111/j.1466-8238.2010.00540.x, 2010.
Skamarock, W. C., Klemp, J. B., Dudhia, J., Gill, D. O., Liu, Z., Berner, J., Wang, W., Powers, J.G., Duda, M.G., Barker, D.M., Huang, X.-yu.: A Description of the Advanced Research WRF Model Version 4.3, No. NCAR/TN-556+STR, doi:10.5065/1dfh-6p97, 2021.
Slivinski, L. C., et al.: Towards a more reliable historical reanalysis: Improvements for version 3 of the Twentieth Century Reanalysis system, Q. J. R. Meteorol. Soc., 145(724), 2876–2908, doi:10.1002/qj.3598, 2019.
Stucki, P., Martynov, A., Pfister, L., Brönnimann, S., Brugnara, Y.: Dynamical downscaling of a cold-air outbreak in the European Alps during the Year Without Summer 1816, in prep. For Clim. Past, 2022.

University of Bern, Institute of Geography, Hallerstrasse 12, 3012 Bern – contact: lucas.pfister@giub.unibe.ch

b
UNIVERSITÄT
BERN

OESCHGER CENTRE
CLIMATE CHANGE RESEARCH